**Coccygeal vertebral damage in a multiparous mare following head and tail rope assisted recovery from general anaesthesia**

**Running Title – Coccygeal vertebral damage following rope assisted recovery**

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**Summary**

An 18-year-old multiparous Thoroughbred mare with a two-month-old foal at foot presented for investigation of colic. A right dorsal displacement of the large colon with a retroflexion of the pelvic flexure was corrected under general anaesthesia and interventional recovery using head and tail ropes was performed. The mare made multiple attempts to stand, using the ropes for support before achieving and maintaining a standing position. The following day, marked swelling around the perineal and vulval region was noted, combined with reduced tail tone. Urination, but not defaecation, had been observed following surgery. Transrectal ultrasonography indicated formation of a haematoma adjacent and ventral to the caudal sacral and first coccygeal vertebrae. Initial radiographic evaluation was suggestive of an oblique fracture of the caudal endplate of the first coccygeal vertebrae, which was confirmed on repeat radiography seven days later. Treatment included cold compresses to reduce swelling, multimodal analgesia, dietary modification to soften faecal consistency and regular manual evacuation of the rectum to avoid impaction. The mare was discharged after 19 days hospitalisation, gradually recovered the ability to defaecate and produced a viable foal the following year without assistance.

**Keywords**

Horse, Anaesthesia, Recovery, Fracture, Mare

**Introduction**

General anaesthesia of horses is associated with a mortality rate of 0.6 - 0.9% in healthy horses anaesthetised for elective procedures, but substantially higher for horses undergoing emergency abdominal surgery (Johnston *et al.* 1995; Johnston *et al.* 2002; Gozalo-Marcilla *et al.* 2021). Catastrophic orthopaedic trauma sustained during recovery from anaesthesia remains the greatest cause of mortality (Bidwell *et al.* 2007; Dugdale *et al.* 2016). Interventional systems, including the use of head and tail ropes, have been developed in order to reduce this risk. They are not, however, without complication (Ruegg *et al.* 2016; Niimura del Barrio *et al.* 2018; Arndt *et al.* 2020; Nicolaisen *et al.* 2022).

To the authors’ knowledge, this is the first reported case of a mare sustaining coccygeal vertebral fracture and secondary neuropathy following use of a head and tail rope recovery system.

**Case Presentation**

A 600kg, 18-year-old multiparous Thoroughbred mare was presented for emergency investigation of colic of four hours duration. The mare was three weeks in foal with a two- month-old foal at foot. A presumptive diagnosis of large colon displacement was made and medical management initiated. Colic signs persisted over the following 30 minutes and it was elected to perform an exploratory laparotomy. Clinical variables on presentation are summarised in Table 1.

Pre-anaesthetic medication consisted of romifidine (Sedivet, Boehringer Ingelheim Ltd) 0.1mg/kg bodyweight intravenously (IV) and morphine (Morphine sulphate, Wockhardt) 0.2mg/kg IV. General anaesthesia was induced with ketamine (Anesketin, Dechra) 2.7mg/kg combined with midazolam (Dormazolam, Dechra) 0.07mg/kg IV. Phenylbutazone (Equipalazone, Dechra) 4.4mg/kg IV had been administered previously, on admission. Procaine penicillin (Depocillin, MSD Animal Health) 20mg/kg IM and gentamicin (Genta-Equine, Dechra) 6.6mg/kg IV were administered preoperatively. Anaesthesia was maintained with isoflurane (Isofane, Henry Schein) vaporised in 100% oxygen. Total anaesthesia time was 125 minutes with one episode of hypotension lasting less than 5 minutes, during which mean arterial pressure (MAP) decreased to 54mmHg and an infusion of dobutamine (Dobutamine concentrate (12.5 mg/ml), Hameln) at 1µg/kg/min IV was initiated. MAP remained between 62 - 88mmHg for the remainder of the anaesthetic period. Arterial blood samples were taken intermittently during surgery and identified mild hypokalaemia and hypocalcaemia which were treated by addition of supplementary potassium chloride 20mmol/L (Potassium Chloride 15%, Hameln) and calcium borogluconate 4mg/mL (Calciject 40, Norbrook) to commercially available Hartmann’s solution (Aqupharm 11, Animalcare) administered IV (Borer & Corley 2010a, Borer & Corley 2010b). Supplemented fluids were then administered at approximately 4ml/kg/hr. Arterial blood results are summarised in Table 2. Exploratory laparotomy confirmed right dorsal displacement of the large colon with a retroflexion of the pelvic flexure, which was corrected and then the contents evacuated via a pelvic flexure enterotomy.

Following completion of surgery, the horse was placed in right lateral recumbency in a padded recovery box. Romifidine 20 µg/kg IV was administered and oxygen supplementation provided. Recovery was assisted using a head and tail rope system employing a static, pre-tensioned tail rope and manually controlled head rope, requiring only one operator (Wilderjans 2008, Niimura del Barrio *et al.* 2018). Forty minutes after being placed in the recovery box, the horse attained sternal recumbency, followed by a first attempt to stand one minute later. During attempts to stand, the mare lost her hindlimb footing several times and fell awkwardly, resulting in a number of instances of sudden increased tension on the tail rope. Following four attempts, the mare was able to maintain a standing position, 45 minutes after moving to the recovery box, and was weight bearing on all four limbs. Recovery quality was assessed as 3/5 based on a descriptive scale modified from that described by Young and Taylor (1993) (Table 3). Head and tail ropes were removed approximately fifteen minutes after the horse achieved a standing position when it was judged to be sufficiently co-ordinated and stable that they were no longer required. The foal was re-introduced to the mare once deemed safe to do so.

**Clinical Findings**

Following return to the stable, the mare remained comfortable with no evidence of overt lameness. However, within 24 hours of recovery the mare was noted to have extensive soft tissue swelling associated with the semimembranosus, semitendinosus and caudal gluteal muscles, extending to the perineal and vulva region (see Fig. 1a). The mare had reduced tail tone, was reported to be urinating normally (although without elevating her tail when doing so), but had not defecated since surgery. Neurological evaluation revealed no evidence of gait deficits but did revealed reduced anal tone. Manual palpation and transrectal ultrasonography identified a firm to fluctuant painful swelling immediately adjacent and ventral to the caudal sacral and first coccygeal vertebrae, consistent with haematoma formation. Radiographic evaluation of the sacrococcygeal region was suggestive of an oblique fracture of the caudal endplate of the first coccygeal vertebrae (Figure 1b). The mare was unable to defaecate unaided and manual evacuation of her rectum twice daily was initiated to avoid impaction.

**Treatment**

Cold compresses were applied to the vulva and perianal region every 4 hours. Analgesia consisted of flunixin meglumine (Meflosyl, Zoetis) 1.1mg/kg IV q12h, paracetamol (Paracetamol 500mg tablets, Zentiva) 20mg/kg PO q12h and morphine (Morphine sulphate, Wockhardt) 0.1mg/kg IV q4h. A lumbosacral epidural catheter (Epidural Pain Management Kit, MILA) was placed aseptically 18 hours after recovery from anaesthesia and preservative free morphine (Morphine sulphate (10mg/ml), Hameln.) 0.1mg/kg administered q12h via this route. Once this was initiated, systemic administration of morphine was discontinued. Postoperative antimicrobial treatment with procaine penicillin (Depocillin, MSD Animal Health) 20mg/kg IM q12hr and gentamicin (Genta-Equine, Dechra) 6.6mg/kg IV q24h was continued for three days. Manual rectal evacuation was continued twice daily. Dietary modifications to soften faecal consistency included enteral fluid supplementation with 5L water with added electrolyte powder (EQUIVET Electrolytes, Kruuse) mixed with 1L of liquid paraffin, administered via nasogastric tube twice daily.

Epidural morphine was discontinued after 48 hours, paracetamol and flunixin were discontinued after seven days and non-steroidal anti-inflammatory medication continued using phenylbutazone (Equipalazone, Dechra) 1.1mg/kg PO BID. Additionally, altrenogest (Regumate, MSD Animal Health) 0.044mg/kg PO SID was administered whilst the mare was hospitalised.

One week following surgery, radiography of the sacro-coccygeal region was repeated, and evaluation confirmed an oblique fracture on the caudal endplate of the first coccygeal vertebra (Cd1) with slight displacement of the fracture fragment. Fracture margins were smoothly marginated with no sclerosis, compatible with acute fracture. Chronic degenerative changes between the fifth sacral vertebrae (S5) and Cd1 including endplate sclerosis, facet osteoarthrosis and collapse of the disc space were also identified (Figure 1c).

The mare was discharged into the referring veterinarian’s care 19 days post-operatively. Ultrasonography confirmed the mare was in foal, although viability could not be confirmed at this early stage.

**Diagnosis**

Oblique fracture of the caudal endplate of Cd1 with secondary neuropathy due to sudden excessive tension on tail rope during recovery (Figure 1c)

**Outcome**

The mare was discharged with instructions to be grazed on lush pasture to promote soft faeces. Long fibre, such as hay or haylage, was to be omitted from the diet but short fibre, preferably soaked, was encouraged. Manual rectal evacuation was continued by the referring veterinarian, initially twice daily, reducing in frequency, and finally discontinued as the mare regained ability to defaecate unaided. The owners reported the mare produced a viable, full term foal by unassisted delivery.

**Discussion**

This report discusses a previously unreported complication directly associated with the use of an interventional system designed to reduce the risk of injury during recovery from general anaesthesia in a high-risk patient. General anaesthesia of horses remains a hazardous undertaking. Mortality rate in healthy horses undergoing elective procedures is reported to be close to 0.9%, rising to 7.8% for emergency abdominal surgery (Johnston *et al.* 1995; Johnston *et al.* 2002). Despite recently published data indicating that this situation is improving, the mortality rate of colic patients remains substantially higher (3.4%) than for elective procedures (0.6%) (Gozalo-Marcilla *et al.* 2021). Recovery from anaesthesia is the most critical period, with overall recovery-associated mortality reported to be 1.1%, increasing to 1.6% for horses undergoing emergency colic surgery (Dugdale *et. al.* 2016). Mortality related to catastrophic orthopaedic trauma (defined as sustaining a fracture necessitating euthanasia of the horse on humane grounds), accounts for 38% to 72.4% of cases depending on study design and sample size (Bidwell *et al.* 2007; Dugdale *et al.* 2016; Sun *et al.* 2019).

Brood mares are reported to be at increased risk of catastrophic orthopaedic injury during recovery from anaesthesia due to decreased bone strength (Glade 1993). Pregnancy and lactation result in enhanced calcium mobilisation from maternal skeletal resorption in addition to increased absorption from dietary sources (Kovacs 2001; Kovacs 2014; Lebel *et al.* 2014). Pregnancy and lactation-associated osteoporosis (PLO) is a rare condition in women, attributed to increased bone turnover and decreased bone mass density. Typically, PLO is characterised by occurrence of vertebral body fractures during late pregnancy or the first six weeks post-partum (Phillips *et al.* 2000; Møller*et al.* 2012; Kovacs & Ralston 2015, Yun *et al.* 2017). A similar phenomenon may have contributed to the injury sustained in this case. Metacarpal breaking strength (MBS) in lactating mares has been found to decrease during the first 12 weeks postpartum, even if dietary calcium was supplemented. From 12 weeks onwards, MBS gradually increases, but is not fully restored until up to 24 weeks post-partum. In mares fed a calcium deficient diet, it can take up to 40 weeks post-partum before MBS is fully restored (Glade 1993). Additionally, older mares are reported to be at even greater risk (Bidwell *et al.* 2007). More generally, increasing age has also been identified independently as a risk factor for peri-anaesthetic mortality in horses (Johnston 2005; Hector *et al.* 2020).

In light of the above factors, the case described was considered to present a significant risk of sustaining injury during recovery. The decision to utilise head and tail ropes was therefore taken to attempt to mitigate this risk by intervening in the recovery process.

In endeavouring to reduce recovery-associated injury, several interventional strategies have been described, including post-anaesthetic sedation (typically using alpha-2 adrenergic agonists), manual restraint with hand assisted recovery (mainly reserved for small ponies and foals), sling systems, tilt tables, water tanks, pool-raft recovery systems and head and tail rope assistance (Sullivan *et al.* 2002; Tidwell *et al.* 2002; Taylor *et al.* 2005; Elmas *et al.* 2007; Wilderjans 2008). Although sedation has been associated with a positive impact on recovery quality from inhalant anaesthesia (Matthews *et al.* 1998; Bienert *et al.* 2003; Santos *et al.* 2003), none of these techniques are reported to be devoid of complications and there is conflicting evidence and opinion as to whether they do improve recovery quality and reduce recovery risk overall (Ardnt *et al.* 2020; Nicolaisen *et al.* 2022). Recovery systems such as slings, and hydropools vary in expense and complexity, and require a team of experienced personnel (Tidwell *et al.* 2002; Elmas *et al.* 2007; Taylor *et al.* 2005). Conversely, rope recovery systems are relatively affordable, low maintenance, can be installed in pre-exiting facilities and are adaptable to varying patient size. Whilst these factors do not negate the need for training, or benefit of experience, in the correct use of rope-recovery systems, their relative simplicity likely makes these goals more easily achievable and head and tail rope systems are the most commonly used method of assisting recovery in equine hospitals (Kästner 2010). This technique consists of two ropes, one attached to a purpose-made halter which aids control of direction of horses standing attempts whilst the other, attached to the tail, acts to stabilise attempts to stand (Wilderjans 2008; Arndt *et al.* 2020). Each rope runs independently through metal rings or pulleys anchored into the recovery box walls 2.35-2.5m above floor level, which direct the ropes outside the recovery box where they can be managed by one or two operators (Arndt *et al.* 2020; Nicolaisen *et al*. 2022). A modification to this system, known as the one-man rope recovery system, consists of the tail rope being fixed under tension using a rope braking device positioned outside the recovery box, requiring only one operator to manage the head rope (Wilderjans 2008; Niimura del Barrio *et al.* 2018).
At our institution, recovery boxes are equipped to permit a one-man rope assisted recovery, the decision on whether or not to employ this being at the discretion of the anaesthetist. Factors influencing this decision include patient size, temperament, whether the horse is unbroken or unhandled, degree and duration of pre-operative debility, duration of anaesthesia and location of surgical site which may be disrupted by the presence of a head collar or tail rope. The horse described in this case was an aged, multiparous, lactating brood mare undergoing emergency abdominal surgery, of calm demeanour (when in the company of her foal), broken in and well handled. Therefore, a rope-assisted recovery was the considered the most appropriate choice.

In elective cases, use of a head and tail rope system reduced standing attempts, shortened recovery duration and improve recovery quality in a prospective study of 305 healthy horses (Ardnt *et al.* 2020). However, mortality rates were the same in both rope-assisted and control groups and the use of ropes did not prevent occurrence of fracture or recovery-associated fatalities (Ardnt *et al.* 2020). Two operators were required to use this system with the more experienced operator managing the head rope and giving direction to the less experienced operator managing the tail rope (Ardnt *et al.*2020). Using a similar system, application of head and tail ropes reduced incidence of fatal complications, especially if patients had undergone emergency abdominal surgery in a prospective study of 1252 horses (Nicolaisen *et al.* 2022). Mortality rate in the assisted group was 0.6% compared with 2.2% in the non-assisted group (Nicolaisen *et al.* 2022).

Similarly, inconsistent results are reported in retrospective analyses of single-operator head and tail rope recovery systems where a pre-tensioned tail rope was used. Louro *et al.* (2022) report better recovery quality with rope-assistance in a study of 502 horses recovering from general anaesthesia for surgical management of colic. Conversely, Ruegg *et al.* (2016) did not demonstrate head and tail ropes to be of benefit in a smaller cohort of 200 horses following emergency abdominal surgery. However, these authors state limitations included recovery box design not being ideal for rope recoveries and colic surgeries frequently being performed out of hours when less experienced personnel were in attendance (Ruegg *et al.* 2016). These authors suggest recovery quality may be improved if a recovery box is designed specifically for use with rope recovery, and when ropes are managed by experienced personnel with a good understanding of assisting horses (Ruegg *et al.* 2016).

Complications associated with rope recoveries are reported to be between 0.08 and 15% (Ruegg *et al.* 2016; Niimura del Barrio *et al.* 2018). These include failure of equipment such as loose or broken head collars, tail knot slippage, tail hair breakage as well as facial nerve paralysis and corneal ulceration (Ruegg *et al.* 2016; Nicolaisen *et al.* 2022).

Caudal vertebral body fracture associated with rope recovery has previously been reported. Bird *et al* (2019) described severe hindlimb weakness and ataxia in an aged gelding, secondary to epidural administration of xylazine and mepivacaine, necessitating induction of anaesthesia on safety grounds and transfer of the horse to a recovery box. During subsequent rope assisted recovery the horse became suspended for several seconds from a locked tail rope, when it is believed the injury occurred (Bird *et al* 2019). Unlike the case reported here, however, physiological status, anaesthetic and recovery management were very different. Indeed, the horse sustained multiple injuries during recovery (several unrelated to the use of ropes) and was re-anaesthetised during the recovery phase. Mepivacaine is a local anaesthetic and xylazine has local anaesthetic-like properties, documented to abolish action potential conduction in the sciatic nerve of frogs (Aziz & Martin 1978). It is likely that these drugs, administered epidurally, were a significant contributory factor to the injuries described by Bird *et al* (2019), by affecting hindlimb motor function.

Failure of equipment can have a major impact, with one report of the failure of a halter ring leading to a sudden backward fall resulting in cervical dislocation and death (Ruegg *et al.* 2016). Technical difficulties include ropes twisting around each other requiring release and re-fixing (9/100 cases), rope becoming tangled around horses legs (1/100 cases) and the head rope becoming locked due to a carabiner locking into a wall ring (1/154 cases) (Ruegg *et al.* 2016; Ardnt *et al.* 2020). Human error has additionally been cited as a cause of negative outcomes, with a head rope becoming detached due to an unlocked carabiner (Arndt *et al.* 2020).

**Conclusion**

To the authors’ knowledge, this is the first reported case of a mare sustaining coccygeal vertebral fracture and secondary neuropathy following use of a head and tail rope recovery system. Given the evidence that lactating mares have reduced MBS therefore increasing their risk of long bone fracture, that the risk is exacerbated following emergency abdominal surgery, and suggestion that rope recovery may positively influence recovery quality, the authors believe this remains the most appropriate method of recovering this patient. In review, although calm when with her foal, the mare did get distressed when separated, which may have led to premature attempts to stand during the recovery period, when visual and olfactory signals from her foal were absent. Coccygeal vertebral body fracture and secondary neuropathy is a rare complication of rope recovery but should be an added consideration in cases recovered with the assistance of head and tail ropes.

**Declarations**

The authors declared no conflict of interests.

**Acknowledgements**

The authors would like to thank Marius Conradie for reviewing diagnostic images for this case and providing a radiological diagnosis.

**Figure Legends and Table Headings**

**Figure 1a** Marked swelling of semimembranosus, semitendinosus, caudal gluteal muscles, perineum and vulva 24 hours following recovery from anaesthesia.

**Figure 1b** Initial radiograph of sacrococcygeal region 24 hours following recovery from anaesthesia. Oblique fracture of caudal Cd1 highlighted (red arrows).

**Figure 1c** Lateral radiograph of sacro-coccygeal region one week following colic surgery identifying oblique fracture of Cd1 (red arrows). Chronic degenerative changes also identified include A) mineralisation between dorsal spinous processes (facet osteoarthrosis) and B) end plate sclerosis.

**Table 1** Summary of Presenting Signs

**Table 2** Summary of arterial blood gas samples

**Table 3** Recovery Scoring System (modified from Young and Taylor 1993)

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